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(54) A METHOD OF DETERMINING PARALLAX EFFECTS IN A STEREOSCOPIC OPTICAL SYSTEM

(71) We, Ernst Leitz Wetzlar Gesellschaft mit beschrankter Haftung, of Postfach 2020, 6330 Wetzlar, German Federal Republic, a limited liability company organised under the laws of the German Federal Republic, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

The present invention relates to a method of determining parallax effects in stereoscopic optical systems and relates to such an optical system incorporating apparatus for determining parallax effects.

It is often desired to determine automatically the parallax effects between two partial images. This applies for example to rangefinders or to the evaluation of aerial stereo-images. For this, different systems for the opto-electrical scanning as well as different systems for the further processing of the electrical signals then arising have already been proposed.

One such known arrangement is shown in Fig. 1, in which the fundamental of the arising signals is utilised. Two lenses 10 and 11 determine the position of respective paths of light derived from an object (not shown) by way of deflecting mirrors 12, 13, 14 and 15 and focused on an optical grating structure 16. As indicated by the double-headed arrow, the grating 16 is mounted to be movable perpendicularly to optical axes 18 and 19 by drive means 17¹. The drive means 17¹ is energised from an electrical signal generator 17. Photoelectric receivers 20 and 21 are respectively associated with the optical axes 18 and 19 to transform light fluxes penetrating the optical grating structure 16 into corresponding electrical signals. Respective phase discriminators 22 and 23 each controlled by a reference signal derived from the generator 17, are connected behind the receivers 20 and 21. The output of the discriminator 22 associated with the first channel is connected by way of a regulator element 24 to the drive means 17¹ of the grating structure 16. The output signal from the discriminator 23 is applied by way of a regulator element 26 to a drive mechanism 25 which can pivot the mirror 15 in the direction indicated by the double arrow.

The mode of operation of this arrangement is such that the first channel determines the spatial phase difference and through the regulator element 24 displaces the mean position of the grating structure 16 until the output signal of the regulation element has become zero. The phase discriminator 23 in this case indicates the parallax. The resultant parallax is equalised to zero through the regulator element 26 and the drive mechanism 25 for the mirror 15.

Here, it is disadvantageous that two regulating circuits are needed, which are coupled with one another through the grating structure.

In the United States Patent Specification 3 710 124, a process is described, which proceeds from the fundamental and the second harmonic. The disadvantage of what is described there resides therein that, as can be shown, the accuracy of the measurement result depends upon the accuracy with which the amplification has been adjusted, which in turn depends on the amplitudes of the fundamental and the second harmonic.

According to one aspect of the present invention, there is provided a method of determining parallax effects in a stereoscopic optical system provided with an optical grating moving through the paths of optical imaging fluxes from an object viewed by the system and falling on two respective photoelectric detectors, producing corresponding electrical signals exhibiting amplitude modulation due to said grating movement, said method comprising the steps of subtracting one of the two signals from the respective other one to provide a difference signal, differentiating one of the two signals to provide a differentiated signal, multiplying the differentiated signal by the difference signal to provide a product signal, and con-

trolling at least one of indicator means and servo-means of the optical system in dependence upon a control signal responsive to the product signal.

According to another aspect of the present invention, there is provided a stereoscopic optical system comprising imaging means, an optical grating moving during use through the paths of imaging fluxes, from an object viewed by the imaging means and falling on two respective photoelectric detectors, producing corresponding electrical signals exhibiting amplitude modulation due to said grating movement, differencing means to subtract one of the two electrical signals from the respective other one, differentiating means to differentiate one of the two electrical signals, and multiplier means to multiply the differentiated signal by the difference signal, the arrangement being such that a control signal responsive to the product signal and indicative of parallax effects is applied to control at least one of indicator means and servo means of the optical system.

Embodiments of the present invention will now be more particularly described by way of example with reference to the accompanying drawings, in which:—

Fig. 1 shows a known optical system incorporating apparatus for the automatic determination of parallax which has already been described with reference to the background of the invention;

Fig. 2 shows an optical system incorporating apparatus for the automatic determination of parallax in accordance with a first embodiment of the invention; and

Fig 3 shows an optical system incorporating apparatus for the automatic determination of parallax in accordance with a second embodiment of the invention.

Referring now to Figs. 2 and 3 of the accompanying drawings, Fig. 2 shows optical imaging means in the form of two lenses 10 and 11 which determine the respective positions of two paths of light derived from an object (not shown) which is imaged by way of deflecting mirrors 12, 13, 14 and 15 on to an optical grating structure 16. The grating structure 16 is mounted to be movable perpendicularly to optical axes 18 and 19 of the paths of light reflected from the mirrors 13 and 14. The grating structure 16 is displaced by electrical drive means 31 energised from a signal generator 30. Photoelectric receivers 20 and 21 convert light components, which have passed along the respective optical axes 18, 19 and through the optical grating structure 16, into electrical signals. The output of the receiver 20 is connected to the input terminals of a differentiating stage 32 as well as to a subtraction stage 33. The output of the other receiver 21 is connected to the second input of this stage 33. The outputs of the stages 32 and 33 are applied to respective inputs of a multiplication stage 34, the output signals of which may, optionally, be passed through an additional smoothing stage 35 and are then applied to drive a servo motor 25 which acts on the pivotable mirror 15. An indicator element 36 may also be provided. The arrangement described so far is applicable when the grating structure is always moved in one direction as, for example, when the optical grating structure is in the form of either a rotatable disc or a rotatable drum.

There are however now some applications in which rotatable optical gratings of this kind would require too much space within the apparatus. In these circumstances, it is usual to employ a rectilinearly oscillatable grating structure which can be kept sufficiently small. On such oscillatable grating structures being used, it is advantageous to utilize the apparatus which is illustrated schematically in Fig. 3. In the apparatus shown in Fig. 3, a multiplication stage 34 has connected behind it a further multiplication stage 40, the second input of which is acted upon by a reference signal, which is proportional to the speed of the motion of the grating structure. This reference signal may be generated in different ways. Thus, the drive means 31 may be energised from an electrical signal generator 42, which is provided with a further output which delivers the desired reference signal. Alternatively, the reference signal may be derived directly from the signal which is applied to the drive means 31, for example by means of a differentiating stage 43 which is shown in broken lines in Fig. 3. It is also possible to obtain this reference signal from an additional photo-electric receiver 44, which scans the optical grating structure 16 directly. Such a photo-electric receiver is likewise illustrated in broken lines in Fig. 3.

The output signal of the multiplier stage 40 then drives the servomotor 25, which acts on the pivotable mirror 15. As indicated in broken lines in Fig. 3, a smoothing stage 35 may be connnected between the multiplier 40 and the motor 25.

The multiplier stage 40 may be in the form of an analogue multiplier, a phase-sensitive detector, an electronic switch, or a ring modulator.

Thus, in the preferred embodiment only one regulating circuit is present, which results in a better dynamic behaviour. Moreover, only a minimum averaging time is required and band-pass filters are not required. Furthermore, null-methods may provide significant advantages in respect of the minimization of systematic and random errors.

Although in the preferred embodiments, the optical grating structure 16 is oscillatorily displaced by drive means 31 in a direction perpendicular to the axes 18 and 19 of the optical fluxes from which the two electrical signals are derived by the photo-electric detectors 20 and 21, relative motion between the image and the grating structure may be obtained as a result of movement of the object, and hence of its image, relative to the optical grating structure 16. Moreover, such relative motion may not be exclusively in a direction perpendicular to the optical axes 18 and 19 but should have at least a component in this direction.

WHAT WE CLAIM IS:—

1. A method of of determining parallax effects in a stereoscopic optical system provided with an optical grating moving through the paths of optical imaging fluxes from an object viewed by the system and falling on two respective photoelectric detectors, producing corresponding electrical signals exhibiting amplitude modulation due to said grating movement, said method comprising the steps of subtracting one of the two signals from the respective other one to provide a difference signal, differentiating one of the two signals to provide a differentiated signal, multiplying the differentiated signal by the difference signal to provide a product signal, and controlling at least one of indicator means and servo-means of the optical system in dependence upon a control signal responsive to the product signal.

2. A method as claimed in claim 1, comprising the further step of multiplying the product signal by a reference signal indicative of speed of motion of the optical grating structure means to derive the control signal.

3. A method as claimed in either claim 1 or claim 2, comprising the further step of smoothing the control signal.

4. A method of determining parallax effects in a stereoscopic optical system as claimed in claim 1 and substantially as hereinbefore described with reference to Fig. 2 of the accompanying drawings.

5. A method of determining parallax effects in a stereoscopic optical system as claimed in claim 1 and substantially as hereinbefore described with reference to Fig. 3 of the accompanying drawings.

6. A stereoscopic optical system comprising imaging means, an optical grating moving during use through the paths of imaging fluxes, from an object viewed by the imaging means and falling on two respective photo-electric detectors, producing corresponding electrical signals exhibiting amplitude modulation due to said grating movement, differencing means to subtract one of the two electrical signals from the respective other one, differentiating means to differentiate one of the two electrical signals, and multiplier means to multiply the differentiated signal by the difference signal, the arrangement being such that a control signal responsive to the product signal and indicative of parallax effects is applied to control at least one of indicator means and servo means of the optical system.

7. An optical system as claimed in claim 6, comprising further multiplier means to multiply the product signal from the first-mentioned multiplier means and a reference signal indicative of speed of motion of the optical grating structure means, the control signal being derived from the output of the further multiplier means.

8. An optical system as claimed in claim 7, comprising a differentiating element to generate the reference signal in response to a drive signal which is applied to drive means for imparting the motion to the grating structure means.

9. An optical system as claimed in claim 7, comprising sensing means to generate the reference signal in response to the motion of the grating structure means.

10. An optical system as claimed in claim 7, wherein drive means for imparting motion to the grating is controlled by a signal derived from one output of a signal generator, the reference signal being derived from a further output of the signal generator.

11. An optical system as claimed in any one of claims 7 to 10, wherein the further multiplier means comprises a phase-sensitive rectifier.

12. An optical system as claimed in any one of claims 7 to 10, wherein the further multiplier means comprises an electronic change-over switch.

13. An optical system as claimed in any one of claims 7 to 10, wherein the further multiplier means comprises a ring modulator.

14. An optical system as claimed in any one of claims 6 to 13, comprising smoothing means for smoothing the control signal.

15. An optical system as claimed in any one of claims 6 to 14, comprising binocular optical means.

16. An optical system as claimed in any one of claims 6 to 15, comprising optical range-finder means.

17. A stereoscopic optical system substantially as hereinbefore described with

reference to Fig. 2 of the accompanying drawings.

18. A stereoscopic optical system substantially as hereinbefore described with reference to Fig. 3 of the accompanying drawings.

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1582462 COMPLETE SPECIFICATION

2 SHEETS *This drawing is a reproduction of the Original on a reduced scale*

Sheet 1

Fig. 1

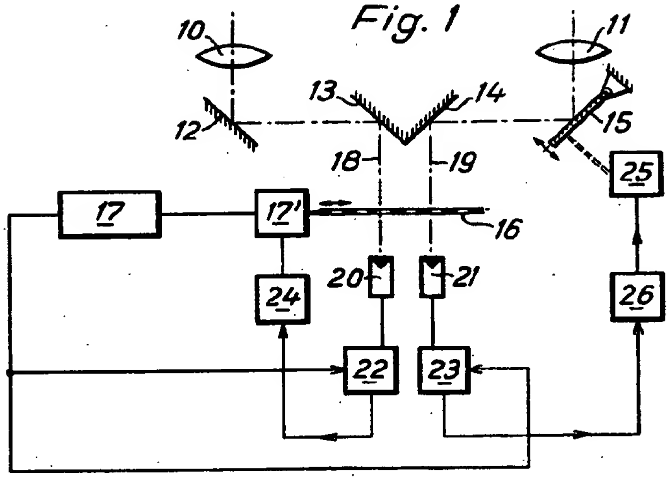
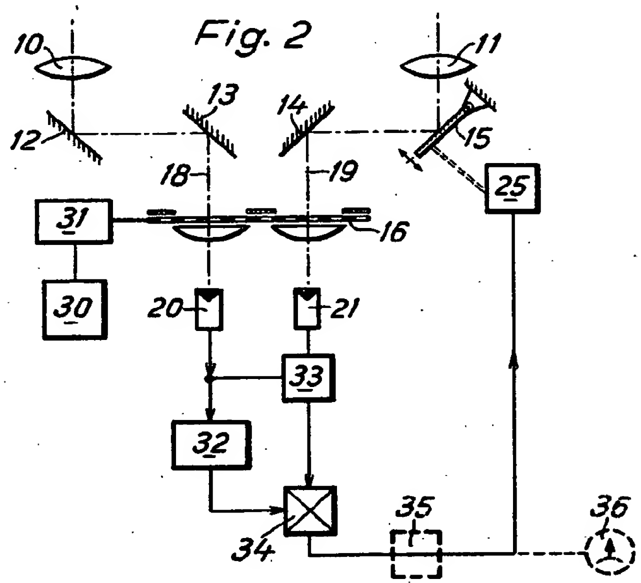


Fig. 2



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Sheet 2

Fig. 3